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VARIABLE VELOCITY PROJECTILE LAUNCHER (LOW LETHALITY)

R. S. Zelina, et al

AAI Corporation

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This report summarizes design, fabrication, and testing efforts conducted in conjunction with the development of a man-portable, variable velocity projectile launch device. The device was configured to launch one-inch diameter rubber balls (high-Q-spheres) at variable velocities designed to harrass, stun or extensively damage point and area personnel targets found in typical scenarios where less lethal weapons would be employed. This would give the tactical commander a so called "green light", "yellow light", and "red light"

(see reverse side)

20. ABSTRACT

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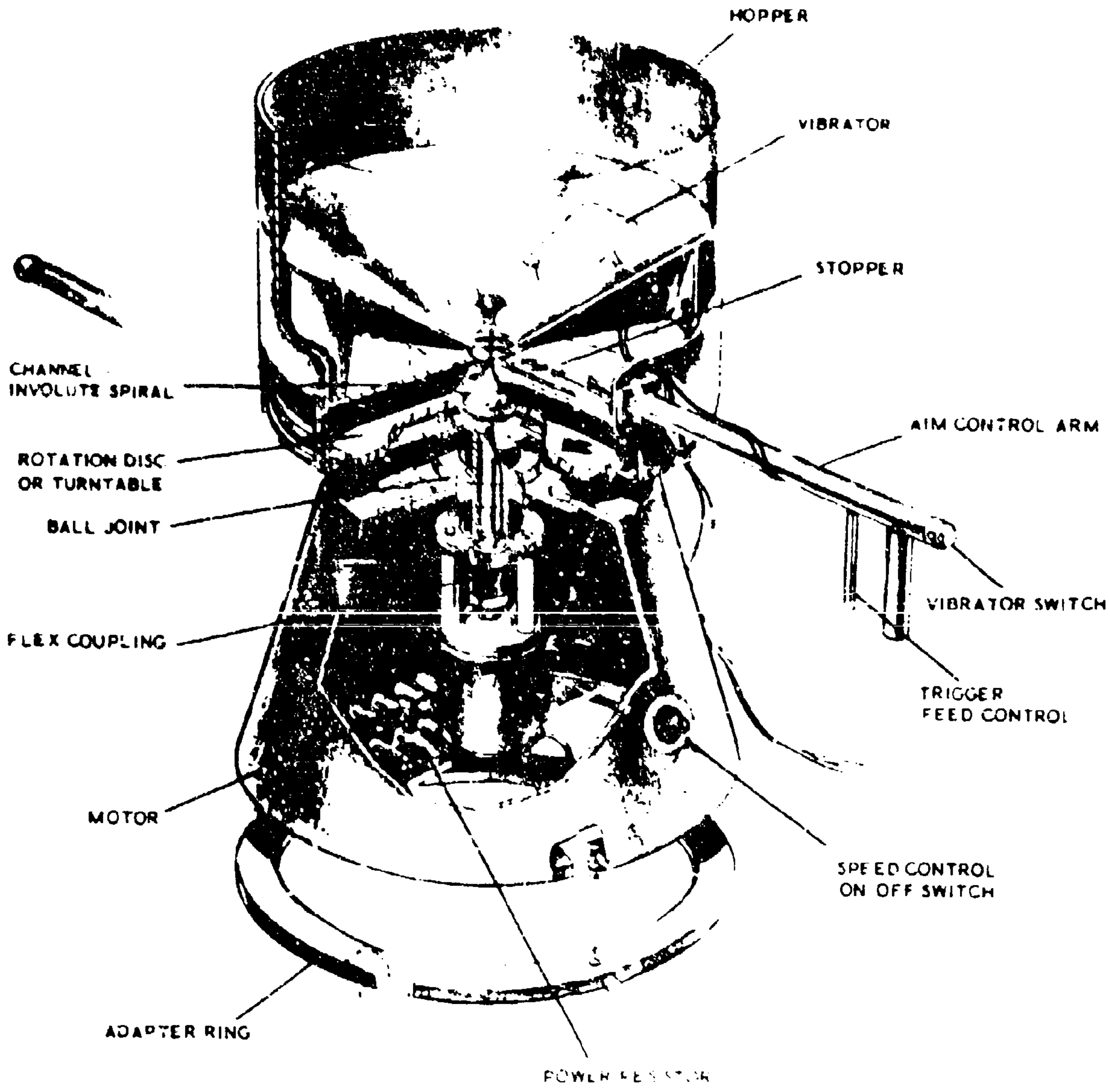

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SUMMARY

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PREFACE

The variable velocity launcher work described in this report was performed under Contract No. DAAD05-72-C-0292 during the March 1973 through March 1974 time period. Results of physiological investigations conducted with the high-Q-spheres impacted against animals under controlled laboratory conditions are presented in companion reports.*

AAI Corporation acknowledges the technical contributions of M. J. Wargovich, LWL Project Officer, to this program. These included the basic concept for utilizing a variable velocity turntable to centrifugally launch high-Q-spheres.

*Zelina, R.S., Analysis of the High Energy-Q-Sphere (Superball) Impacted Against Laboratory Animals (Low Lethality), March 1972, AAI ER-6923.

*Wargovich, M.J., Zelina, R.S., Tiedemann, A.F., Jr., Evaluation of Physiological Effects of High-Q-Spheres Impacted Against Laboratory Animals, Final Report Vol. I and II, July 1973, AAI ER-7436.

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I. INTRODUCTION

This letter report summarizes design, fabrication and testing efforts conducted during development of a man-portable, variable velocity projectile launch device.

A. Background

Discussions with control forces which have recently been called upon to resolve civil disturbances indicate that illegal crowds tend to disperse most readily when confronted with sudden overwhelming force which produces a shock or stun effect. This phenomenon is well known to line commanders who continually strive to have this "shock effect" incorporated in all manner of lethal weapons.

In dealing with civil disturbances, we see that the ideal weapon should incorporate a high degree of shock (or stun) effect, while minimizing physiological damage to the dissidents.

For situations involving one or several fleeing suspects, one would ideally like to deliver a munition or munitions which would stun the suspects to halt their flight and facilitate their speedy apprehension. Here again, this should be accomplished with a minimum of physiological damage inflected upon the suspects.

In the event that the situation warrants the use of force which exceeds less lethal levels, it would be appropriate to increase the damage level to a point which is commensurate with the requirements of the situation. This could be done by providing three launch velocity options

controlled by buttons or a rotary switch, i.e., green for harrass, yellow for stun, and red for lethal. A fail safe lock, operated by the commander, could be incorporated to preclude inadvertent use of an excessive launch velocity.

Considerable work has been done in connection with the use of kinetic energy type less lethal damage mechanisms, such as the British rubber bullet, water ball, bean-bag, etc. Relatively little hard information is available which establishes the physiological damage produced by target impacts with these mechanisms. Also, the capability of these munitions to disperse illegal crowds, stop fleeing suspects, etc. has not been established.

On the other hand, considerable work has already been done by LWL to establish the physiological damage produced by high-Q-sphere impacts. Furthermore, considerable progress has been made in establishing the estimated capability of spheres to disperse illegal crowds, stop fleeing suspects, etc. These estimates are being generated under a program wherein medical and physiological personnel utilize experimental physiological data derived from controlled animal tests to estimate the effects on human targets engaged in various illegal activities. Desirable and undesirable effects estimates are being made, utilizing the physiological data base which is augmented with psychological effect inputs.

The man-portable concept shown on the frontispiece is designed to launch high-Q-spheres at variable velocities to harrass, stun or extensively damage point and area personnel targets. The device is man-portable and operates in the single-shot or semi-automatic fire modes. A 12 volt D.C. battery provides the power source.

Although the device shown herein is man-portable and D.C. powered, growth versions could of course be vehicle mounted, A.C. powered, etc. Some concepts along these lines are shown for reference purposes in Appendix B.

The device fills a current need as it provides a useful tool for conducting further research with high-Q-spheres. It can be used to conduct additional animal tests to investigate shock effects (possibly a key parameter in the dispersal of illegal crowds) and could, possibly, also be used in similar experiments involving human volunteers.

B. Objective

The primary objective of the program was to provide a useful tool for conducting additional physiological tests involving laboratory animals and the high-Q-sphere.

In addition, the program was to provide an advanced prototype less-lethal device which uses the high-Q-sphere as a stun mechanism.

C. Design Criteria

The following criteria represent desirable design goals:

- Range - 20 to 70 meters
- Launch Velocity - 100 to 500 fps
- Launch Azimuth - 360°
- Launch Elevation - $\begin{matrix} +45^\circ \\ -20^\circ \end{matrix}$
- Accuracy - 20 mil CEP
- Power Supply - 12 V.D.C.

- Man Portable
- Weight - 30 lb. (excluding payload and power supply)
- Safety - incorporate safety locks which facilitate launching at varying velocities as follows to obtain desired target effects:

Green	-	harrass
Yellow	-	stun
Red	-	lethal

  The red lock is to incorporate a fail-safe key.
- Firing rate - single shot through full automatic.

II. SUMMARY

A prototype device, capable of launching high-Q-spheres singly and semi-automatically at variable velocities has been developed and subjected to preliminary performance tests.

The device is man portable, weighs 44 lbs., excluding a 12 V.D.C. power supply, and has successfully launched high-Q-spheres at velocities up to 167 fps*, singly and at rates of approximately sixty shots per minute. The circular error probability (CEP) of the device averages 106 mils.

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* This corresponds to a launch kinetic energy of 12.7 ft-lb.

III. DESIGN CONCEPT

A. Description

The design concept of the variable-velocity high-Q-sphere launcher is shown in Figure 1. The launcher has an overall height of 24½ inches and a maximum diameter of 15 inches at the base. Its empty weight is 44 pounds. When filled with 1.09-inch-diameter spheres (capacity, 600 spheres) its weight is increased by 15 pounds. The machine is composed of the following nine units which will be described in the order presented:

- Base
- Adapter Ring
- Drive
- Ball Joint
- Hopper
- Aim Control
- Feed Control
- Speed Control

The base has the shape of the frustum of a cone to provide stability for the machine and clearance for the hopper which is tilted during elevation adjustment. It houses the motor, wiring and speed control components. The construction is primarily of welded aluminum. The top plate and bottom ring are both 1/4 inch thick and the skin is .063 inch. Bolted to the bottom ring are three pointed feet which are inserted into the earth when the machine is used on the ground.

These same feet can be inserted into the holes in the adapter ring and held in place by three thumb screws. The bottom of the adapter ring has three rubber suction pads which can be used to mount the machine to the top or any other horizontal surface of a vehicle.

The drive system consists of the motor, flex coupling, spindle assembly and rotation disc. The motor is a series wound, 12 vdc, 10,000 rpm, and 3/8 h.p., Prestolite number EML-4003.

The flex coupling, Stock Drive Products part number 521-110, is capable of accommodating the slight misalignment between motor and spindle shafts and is capable of transmitting peak torques to the rotating disc.

The spindle assembly provides a low friction drive between the motor and rotating disc. It consists of a housing with a 12 mm ball bearing mounted at each end to support the shaft. A motor mounting plate, having a left hand thread, is screwed to the lower end of the housing. The left hand thread ensures a locking engagement of the motor mount when it reacts to the starting torque of the motor. A plate to mount the hopper is screwed to the upper end of the housing. Plates at both ends of the housing are locked in place by jam nuts.

Fastened to the upper end of the spindle is the rotation disc, a 3/8 inch thick aluminum plate, 13 inches in diameter. A channel whose path from the center to the periphery of the disc forms an involute is mounted to the top surface of the disc. The channel, 1-1/4 inches high by 1-1/4 inches wide is closed at the center of the disc and spirals in a clockwise direction

to the periphery of the disc where it is open. The leading edge of the outer wall of the channel (where the outer wall meets the disc circumference) is reinforced by a solid block whose function will be described in the next section describing the launcher's operation.

The ball joint is located midway between the end plates of the spindle housing. The ball is sandwiched between two plates which are machined with the ball contour to insure positive clamping. The lower of the two plates is mounted to the top plate of the base. The upper plate provides the clamping by bolting to the lower of the two plates. This arrangement permits sufficient friction to be developed in the ball joint to maintain azimuth and elevation settings and yet enables the operator to alter these settings with ease due to the considerable mechanical advantage of the aiming handle. Elevation adjustment is $\pm 30^{\circ}$; azimuth 360°, $\pm 180^{\circ}$ as limited by an electrical lead which is looped between the base and the hopper.

The hopper is an open-ended cylinder, 13-9/32 inches in diameter by 11 inches long, containing the sphere storage bin and sphere acceleration chamber. The bottom of the storage bin tapers 30° down to an opening at the center of the acceleration chamber. This chamber is just sufficiently high to clear the involute channel on the top surface of the rotating disc.

The outer wall of the acceleration chamber contains a 36° opening which permits the high-Q-spheres to be expelled from the left side of the launcher. The forward and aft edges of this opening are reinforced with a 3/16 inch thick stainless steel bar.

Fixed radially to the hopper is a 12-inch-long arm which furnishes the means for aim control. This length provides a mechanical advantage of 16:1 for overcoming the ball joint friction when aiming the machine in azimuth and elevation. Terminating the arm is a pistol grip and trigger. Compressing the trigger withdraws a flat stopper from the lower opening of the hopper to permit the entry of the spheres into the acceleration chamber.

The feed opening stopper is a flat plate which slides between the underside of the hopper bottom and the top side of the acceleration chamber. In its normal position it is spring-loaded closed, shutting off the supply of balls to the acceleration chamber.

The trigger is fastened to a spring-loaded rod which is located in the tubular aim control arm. The back end of the rod engages a compression spring while the front end is connected to the flat stopper. Also, the vibrator push button switch is located at the end of the aim control arm in easy reach of the thumb. Aiming the launcher and controlling the rate of fire is therefore accomplished with one hand.

Launcher speed is controlled by an on-off 7 position selector switch located on the inclined surface of the base. The switch is wired so that 2 to 14 resistors are added in series to the drive motor. These resistors are conveniently located in the proximity of the switch. They are mounted on a plate which is fastened to the bottom and inside rim of the base.

B. Operation Characteristics

The launcher may be positioned on the ground or on any smooth horizontal surface such as the hood, roof, or trunk of an automobile. In order to stabilize the launcher to the ground, the adapter ring is removed from the base exposing three pointed feet which may be inserted into the ground. With the adapter ring in place, the launcher may be mounted to any convenient horizontal surface of a vehicle. The adapter ring has three suction-cup feet which hold the launcher in place.

The launcher is easily filled with approximately 600 high-Q-spheres since the large opening at the top of the hopper is unobstructed. Filling the hopper to the brim is not recommended, however, since tilting the hopper during elevation adjustment usually results in spillage.

Two 1/4 - 20 terminal posts are provided for connecting a 12 volt battery to the launcher which is indifferent to polarity. Either of these terminals may be connected to the positive or negative posts of the battery.

Launcher speed is adjusted at the on-off and selector switch mounted on the inclined sidewall of the base. In its extreme CCW position the switch is off. Turning the switch knob CW increases the motor speed. There are seven distinct switch positions and corresponding muzzle velocities beginning at the lowest, 63 ft./sec., to the highest, 155 ft.,/sec.

The launcher requires five to ten seconds of time to reach its setting speed, at which time it is ready to fire. When the trigger at the end of the aim control is squeezed, the stopper is retracted, permitting the

spheres in the hopper to fall into the involute channel at the center of the rotating disc. Centrifugal acceleration on the sphere carries it to the periphery of the disc along the outside wall of the channel. As it rolls along the outside wall, this velocity is added* to the launch velocity imparted by the rotating disc if the sphere reaches simultaneously the end of the involute channel and the launch opening of the acceleration chamber. In most cases, the sphere rolls along the inside wall of the acceleration chamber until it reaches the launch opening in the acceleration sidewall. This opening, 36° wide, is just long enough to clear the projected path of the launched sphere. Since there are occasions when the sphere will arrive somewhere near the mid-point of the opening, jamming of the spheres between the aft edge of the channel occurs. In order to prevent the machine from experiencing a violent impact, the reinforced aft edge of the opening is sharpened to present a knife edge to the sphere thus slicing it. A solid block, which is tapered towards the periphery of the disc, reinforces the outer wall of the channel in order to withstand the forces of slicing.

Frequently, the high-Q-spheres will fail to enter the acceleration chamber when the trigger is pulled. This is because the spheres have a high coefficient of friction which increases their tendency to bridge across the opening to the acceleration chamber. It is then necessary to actuate the vibrator switch on the end of the aim control handle. The switch's position is extremely convenient since it can be depressed by the thumb of the same hand which aims and fires the launcher.

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* Thus, the sphere exit velocity is slightly greater than the peripheral disc velocity.

Approximately 10% of the launched spheres are sliced as they exit the launcher. This occurs as they jam against the sharp aft edge of the wall cut-out and the outer edge of the disc channel. Slicing appears to be an integral feature of unsynchronized designs having a limited opening. The designs listed in Appendix A fall in this category, also.

C. Weight Breakdown

The following sub-assemblies are listed to show the weight distribution:

Sub-Assembly	Weight in Lbs.
Base with resistors	9.5
Adapter ring	1.6
Drive	24.3
Motor (5.5 Lbs.)	
Disc (7.25 Lbs.)	
Hopper	7.8
Handle	1.0
Total Weight	44.2

IV. TEST RESULTS

A. Launch Velocity

The sphere launch velocities were measured for several speed settings, 3 through 7, using 5-foot separation lumiline screens. These values are listed in the table below. Corresponding disc RPM's were measured and launch velocities calculated from these values are included in the table. A comparison of these velocities, derived and measured, reveals that the measured velocities are higher for all settings except No. 7. These higher velocities were predicted as explained in the prior section, IV.B.

TABLE I

Velocity and Accuracy Readings For High-Q-Sphere Launcher

Speed Settings	Measured RPM of Disc	Calculated Launch Speed ft/sec	*Measured Velocity of Spheres	CEP (mils)
3	1490	79	83	75.0
4	1630	85	100	64.3
5	1810	95	125	107.1
6	2440	126	139	178.6
7	2970	155	143	107.0

B. Accuracy

Accuracy readings were taken by firing at the center of a 6x8 foot grid which was located 28 feet in front of the launcher. The last column in Table I shown above lists the CEP accuracy in mils.

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* Values represent an average of 5 shots

C. Range

No range measurements were taken in conjunction with the speed settings listed in the prior table. However, at the maximum speed setting an average distance of 150 feet was recorded for launcher elevation of approximately 12 degrees.

V. DISCUSSION

The deficiencies noted in the preceding paragraphs are inherent to the current design of the launcher. The present device is unsynchronized, consequently approximately 10% of the spheres that were launched failed to clear the launch window cleanly and got sliced as they exited. This slicing action tends to jam the device and, of course, scatters missiles indiscriminately in the vicinity of the launcher. To increase the width of the launch window might reduce the slicing action but this would be at the expense of the already unsatisfactory accuracy and would also tend to reduce velocity and, thereby, range.

The maximum desired launch velocity has not been attained. As now configured the launcher is underpowered and the turntable exhibits consierable aerodynamic drag. These characteristics prevent launchings of high Q spheres at 500 FPS which is desired.

The desired accuracy has not been attained. This is a combination of the turntable velocity, the launch window configuration and the combination of effects, rotation and acceleration of the sphere created by action both in the channel on route from the hopper and along the acceleration sidewall.

The most obvious solutions to these problems would be the incorporation of a more powerful drive motor and a feed synchronization component; however, it is doubtful that these design changes could fully overcome the inherent erratic behavior of a bouncing rubber ball being propelled first through a chute and then by centrifugal force around a chamber.

VI. CONCLUSIONS

1. The concept of a device which launches relatively soft projectiles at a predictably variable velocity continues to have merit for civil disturbance application.

2. The variable velocity projectile launcher developed in this task did not meet the design goals initially established, being deficient in accuracy, launch velocity and in the undesirable random slicing of the projectiles.

3. The feasibility of developing a variable velocity projectile launcher which would meet the design characteristics was not established by this developmental effort.

VII. RECOMMENDATION

It is recommended that development be continued to determine (a) the feasibility of the approach initiated by this task and (b) the possibility of achieving a variable velocity launcher through the means of some other concept.

APPENDIX A

ALTERNATE DESIGNS

In addition to the launcher design described in the body of this report (which is referred to as L-2), several alternates were considered and tested experimentally. These alternates are shown in Figures A-1 through A-3. They are all variants of the basic L-2 concept. Differences consist principally of variations in turntable design.

All of the designs investigated employ an eccentric feed located near the center of the rotating turntable. Also, centrifugal force is utilized to carry the ball from the center of the turntable to its periphery. At this point it is either impacted by a paddle (L-1 design) and propelled out of an opening in the outer case of the launcher, forced by a paddle (integral part of the feed chute) through a nozzle of square cross section fitted to the launcher body (L-3 design), or allowed to leave the launcher through an opening in the outer launcher case as the ball guides pass the opening (L-4 design).

Each of the alternate launcher designs is now discussed in terms of performance, problems encountered, etc.

L-1 Alternate Launcher Design

This concept constituted the original design approach on this program. It is a direct descendent of the prototype machine initially produced by LWL. Performance data for L-1 is shown in Table 1A. Considerable variation in measured launch velocities occurred at constant speed settings. This was thought to be due to the jamming of many balls which tended to slow down the turntable speed and to balls impacting part of the outer case while exiting the launcher.

TABLE IA. ALTERNATE LAUNCHER L-1 PERFORMANCE DATA

Speed Setting	Measured Turntable RPM	Calculated Launch Velocity (Ft./Sec.)	Measured* Launch Velocity (Ft./Sec.)		CEP** (Mils)
			Average	High/Low	
3	3550	185	94	167/60	80.4
4	4150	216	91	109/72	71.4
5	4700	244	111	132/104	44.6
6	5400	280	125	185/82	53.6
7	6350	330	N/T		N/T

* Average of approximately 5 to 6 shots with highest and lowest readings.

** CEP = Circular Error Probability = Radius of Circle Containing 50% of Impacts. Excludes erratic shots which failed to hit target.

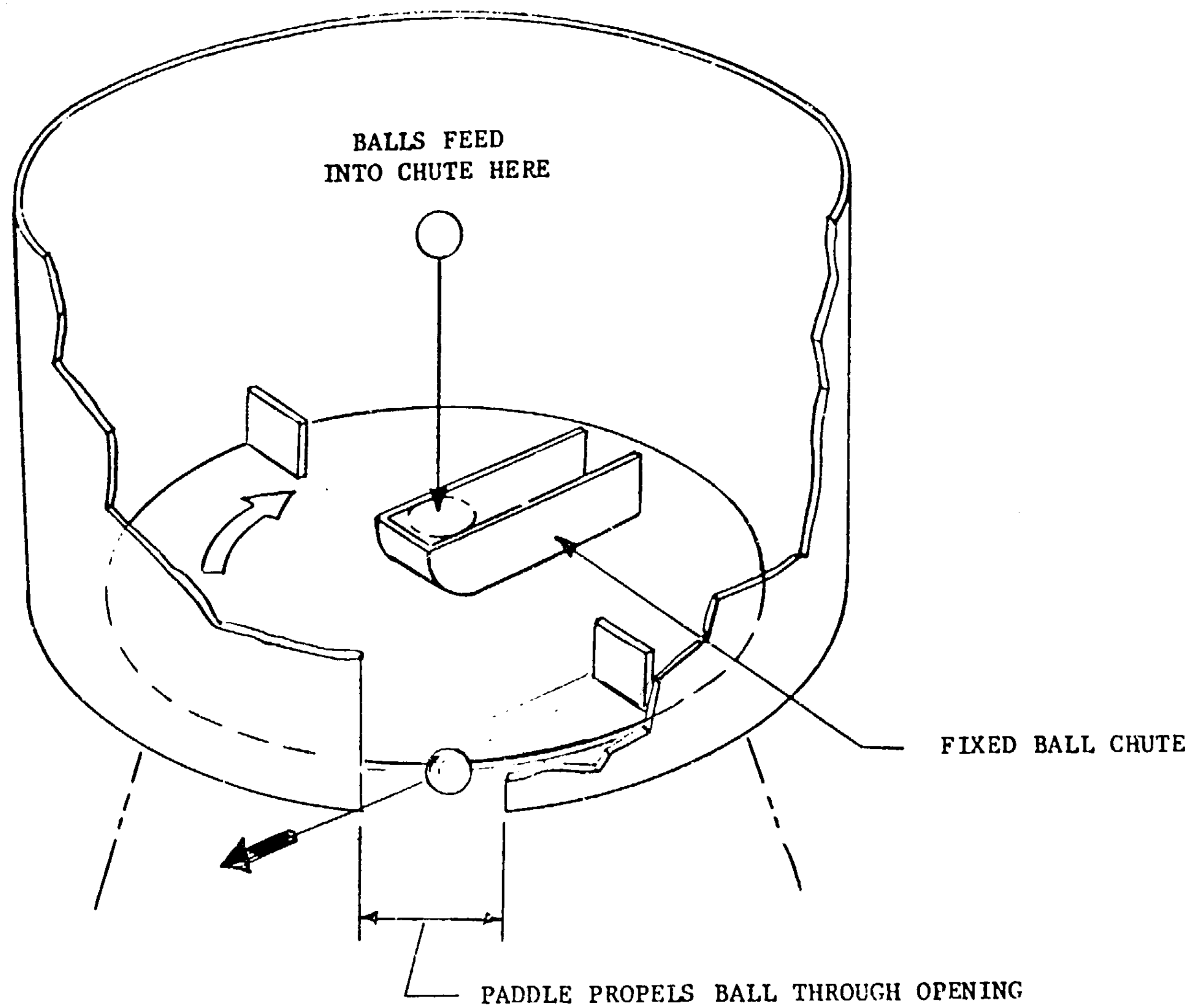


FIGURE A-1. ALTERNATE LAUNCHER DESIGN L-1

L-3 Alternate Launcher Design

This concept was configured to provide a single shot, rapid fire launcher. The primary objective was to launch the high-Q-spheres from a common location (through a nozzle) so as to attain consistent accuracy. This was accomplished. However, the peripheral forward corner of the paddle tended to jam the spheres against the exterior of the nozzle as it swept through the nozzle area. As a result, a high percentage of the spheres were notched by the paddle and suffered a significant velocity loss. Since the concept did not appear feasible in early tests, work on it ceased and quantitative performance data was not obtained.

L-4 Alternate Launcher Design

This concept featured four mutually perpendicular troughs mounted on a rotating turntable. The balls were fed onto the turntable through an eccentrically located feed position. They were then centrifugally accelerated through the nearest trough to the periphery of the turntable, from which they were launched through a narrow opening in the side wall of the launcher case.

Balls were satisfactorily launched at various speeds with this arrangement. However, an occasional ball wedged between the rotating turntable trough and the leading edge of the side wall opening, resulting in considerable damage to the machine. The leading edge of the side wall distorted, the trough was severely deformed, and the motor was dislodged from its mounting. This concept proved to be unsuitable. Testing was discontinued and quantitative performance data was not obtained.

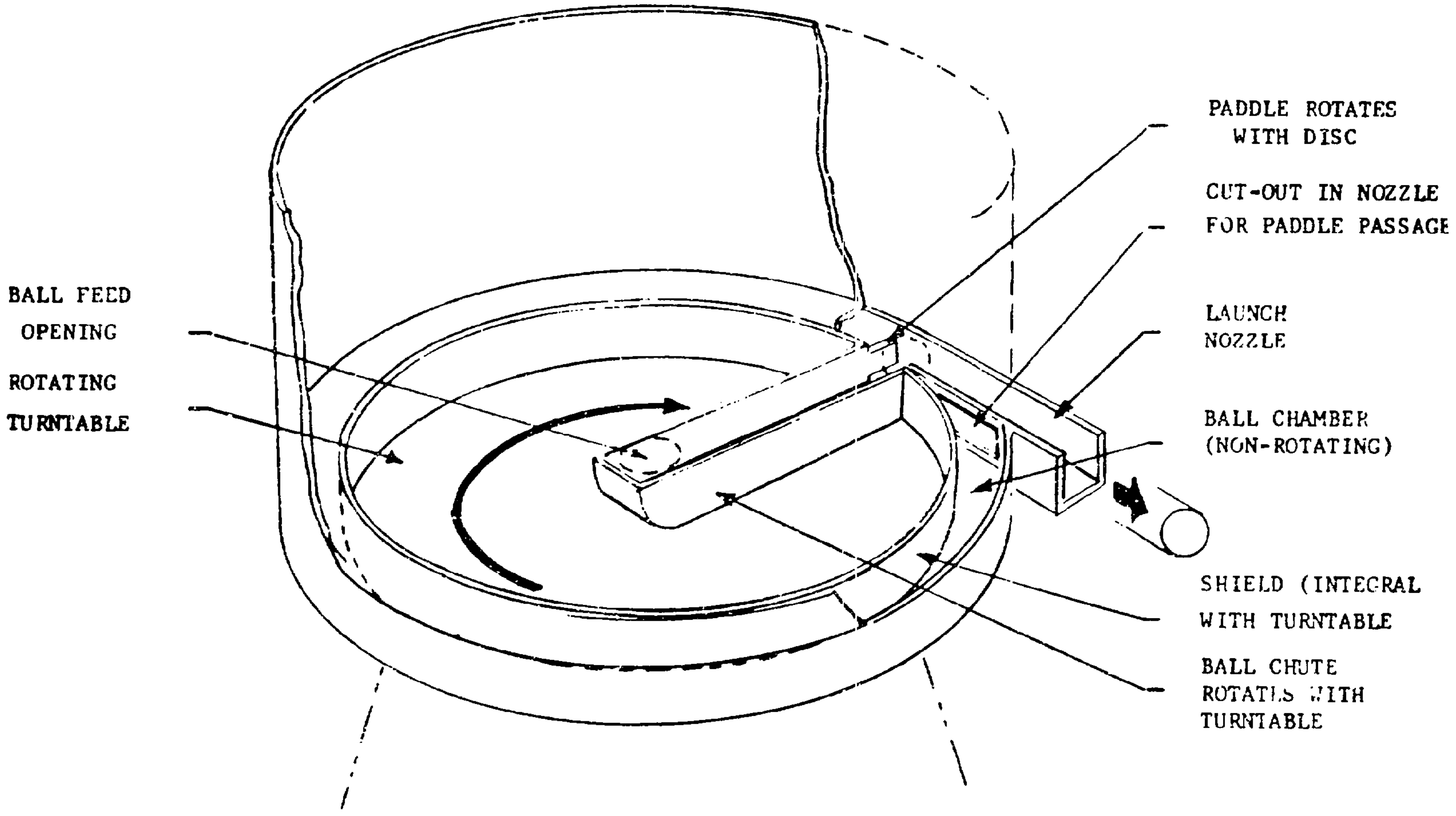


FIGURE A-2. ALTERNATE LAUNCHER DESIGN L-3

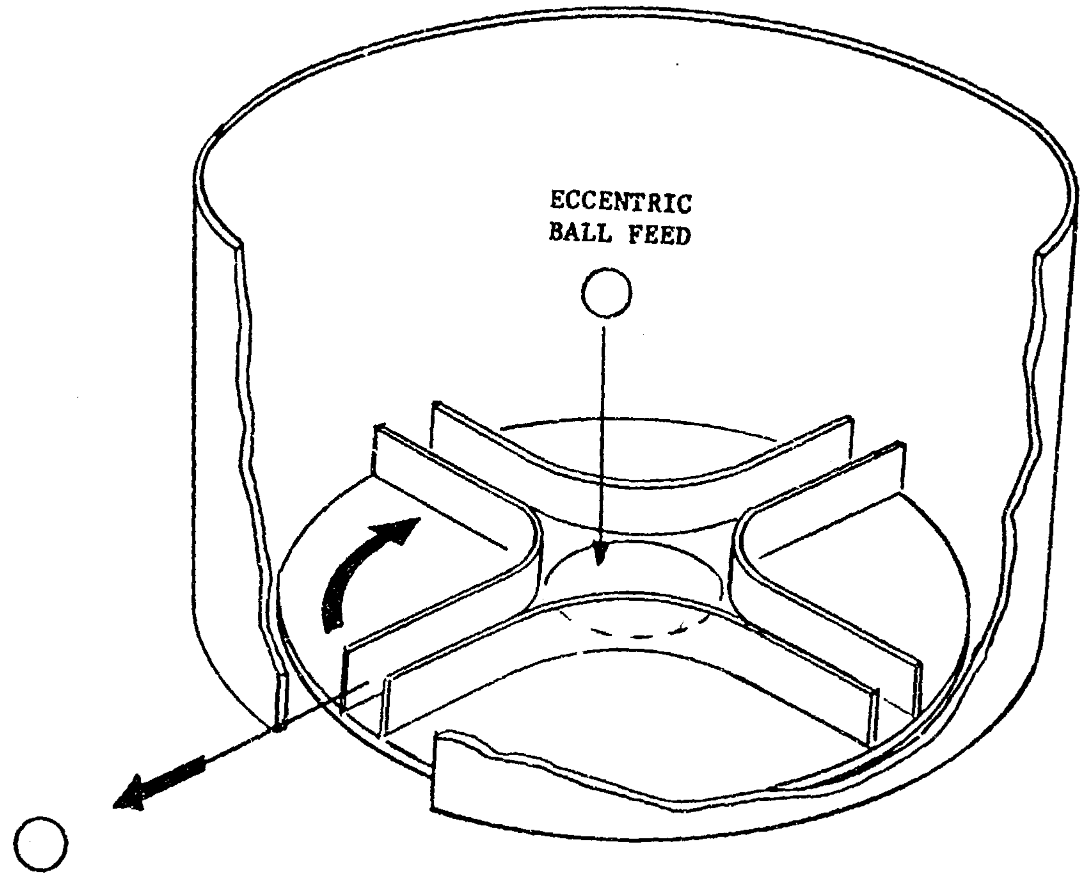


FIGURE A-3. ALTERNATE LAUNCHER DESIGN L-4

APPENDIX B

GROWTH VERSIONS

The launcher described in this report is man-portable and designed for ground based use. However, the launcher can be mounted on a variety of vehicles as shown in Figure B-1. The vehicle battery (12 vdc) could be used to power the launcher. In order to employ the launcher with jeep type vehicles, one need only add a simple adapter stand to the vehicle in order to provide sufficient launcher stability and elevation. The operator could function the launcher in much the same manner employed in the ground based mode.

Mounting the launcher on a sedan type vehicle would be relatively straightforward, utilizing a simple ring adapter. Control could be accomplished manually or via a drive system. The manual system would involve a pistol grip/trigger unit slaved to the basic aiming/control arm. The drive system could utilize two commercially available TV antenna drives (one for azimuth, one for elevation control) with a D.C. to A.C. converter. Here again, the pistol grip/trigger unit would be located remote from the launcher within the vehicle.

In either system, some type of sight would be needed to enable the operator to know at all times the launcher aim point. For the jeep mounted launcher, a simple ring type sight would probably suffice. The sedan mounted launcher would require an internal sighting system slaved to the launcher, or the addition of a cutout in the sedan roof and an elevated jump seat to enable the gunner to operate the launcher from an elevated position. With the latter system, shown in the following sketch, he would

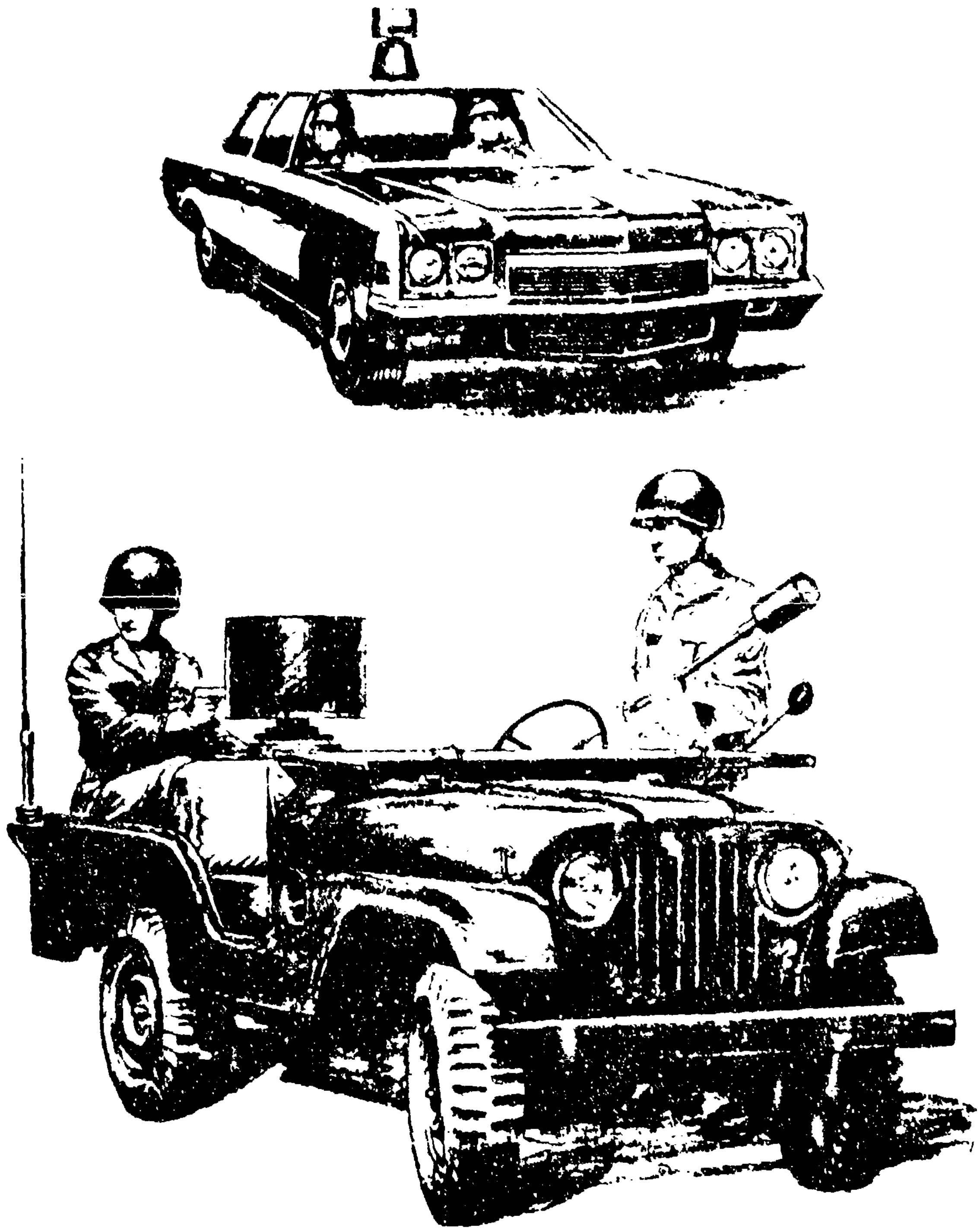
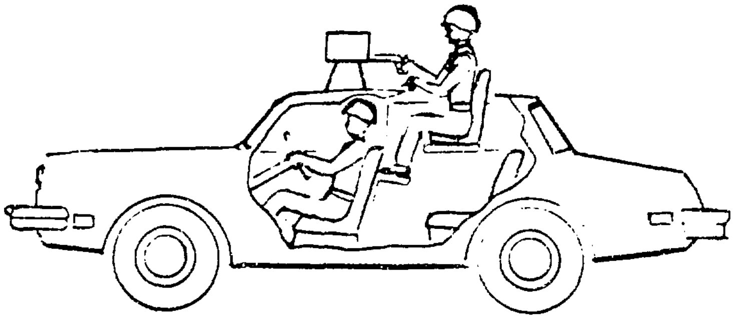


Figure B-1. Vehicle Mounted Launch Systems



operate (load, aim and fire) the launcher in the same manner as he would the jeep-mounted system.

APPENDIX C

ANIMAL TRAINING PROGRAM

PHASE 2, HIGH-Q-SPHERE

ANIMAL TRAINING PROGRAM, PHASE 2

High-Q-Sphere

FINAL REPORT

Submitted to

AAI Corporation
York Road and Industry Lane
Cockeysville, Maryland

HAZLETON LABORATORIES, INC.
9200 LEESBURG TURNPIKE • VIENNA, VIRGINIA • 22180

December 13, 1973

SPONSOR: AAI Corporation **DATE:** December 13, 1973

MATERIAL: High-Q-Sphere **LOT NO:**

SUBJECT: FINAL REPORT
Animal Training Program, Phase 2
Project No. 521-111

I. INTRODUCTION

The purpose of this study was to determine whether effects associated with controlled high-q-sphere impacts on a monkey's head and/or torso would interfere with the performance of a simple task. The kinetic energies were planned to be non-lethal.

II. MATERIALS AND METHODS

A. Animals

Six young sexually mature rhesus monkeys (Macaa mulatta) were used as test subjects. Each of these animals had been trained to repeatedly press a lever switch (modified telegraph key) on a continuous (Sidman) avoidance schedule (see below). The monkeys ranged in weight between 3.0 and 3.9 kilograms.

B. High-Q-Sphere

The high-Q-sphere was launched against the target areas from either a hand-held unit (Monkey No. 226 Code 001) or a bench-mounted unit at velocities ranging from 23.4 to 463.3 f.p.s. thereby delivering from 0.32 to 84.8 ft-lb. kinetic energy.

C. Behavioral Performance Test

The continuous avoidance schedule on which the monkeys had been given training consisted of 0.2" electric shocks delivered at 2.0" intervals through the feet and buttocks until the monkey pressed the response switch. Each successive depression of the response switch postponed delivery of the next shock (600 volts A.C. through 47,000 ohms in series with

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the monkey) for 15 seconds. Failure to make a second response within 15 seconds of the previous response resulted in delivery of a 0.2" shock which could not be escaped. A response during the 2.0" inter-shock interval reset the timers and returned the schedule to the 10" interresponse requirement.

III. RESULTS

Test No.	Monkey No.	Film Code	Impact Area	Velocity f.p.s.
1	226	001	Left Kidney	28.4
	Result:	A speed-up in rate of lever responding. No pauses, no shocks taken.		
2	231	002A1	Left Kidney	173.3
	Result:	Animal cried out on impact. Impact followed by a pause ≈ 5", no shocks taken.		
3	237	003A1	Left Kidney	251.7
	Result:	No discernible change in performance.		
4	224	004A1	Left Kidney	388.5
	Result:	Paused for 12" and took 2 shocks. Then made 2 responses followed by a 14" pause with 3 shocks. Full recovery of performance within 30" after impact.		
5	271	005A1	Left Kidney	410.5
	Result:	No discernible effect from a glancing hit.		
6	271	006B2	Left Kidney	463.3
	Result:	Made 3 responses following impact, then paused for 14" with 2 shocks. Full recovery within 30" after impact.		
7	273	007A1	Left Kidney	378.0
	Result:	Paused for just under 10" after impact. Took no shocks.		

Test No.	Monkey No.	Film Code	Impact Area	Velocity f p.s.
8	226	007B2	Side of Head	30.3
	Result: Paused for 10" after impact. Took 1 shock. Full recovery within 30" after impact.			
9	231	008B2	Side of Head	367.7
	Result: Paused for 10" after impact and took 1 shock. Then made 2 responses followed by another 10" pause with 1 shock. Made 1 response, then paused for 12" with 2 shocks. During next 80" made responses only after 1 shock at 10" intervals. Then full recovery after approximately 115" after impact.			

IV. CONCLUSIONS

While allowance should be made for possible variation in susceptibility among the monkeys, the present results indicated that below 250 f.p.s., the high-Q-sphere impacting the region of the left kidney did not appreciably disrupt the trained performance of the monkeys. Similarly, below approximately 450 f.p.s. such impacts did not incapacitate for 30 seconds or more, although above 378 f.p.s. some momentary interruption of performance was observed.

On the other hand, an impact to the side of the head at 367.7 f.p.s. produced a much more severe disruption from which the animal did not fully recover for almost two minutes, although he remained capable of responding to the shocks throughout.

No direct extrapolation to human ability to withstand similar high-Q-sphere impacts can be made from these data. However, it seems reasonable to predict that with the exception of head impacts at velocities producing tissue

damage, such a blunt trauma mechanism would not incapacitate humans sufficiently to prevent continuance of a highly motivated behavior sequence, although a momentary disruption might follow even lower velocities. Impacts to the torso might be expected to have less behavioral effect even at superficial tissue damaging velocities. No prediction as to the effects on monkeys (or humans) from impacts producing Grade 2 or greater damage can be made since such tests have not been made.

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